

An Optimal Estimation Approach to AIRS CO Retrievals

Stuart MacCallum

Chris Merchant

School of Geosciences
The University of Edinburgh

s.maccallum@ed.ac.uk



Retrieval Method

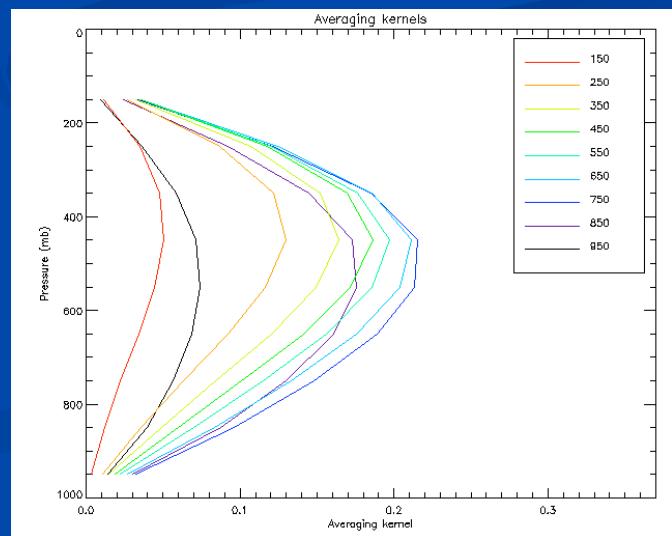
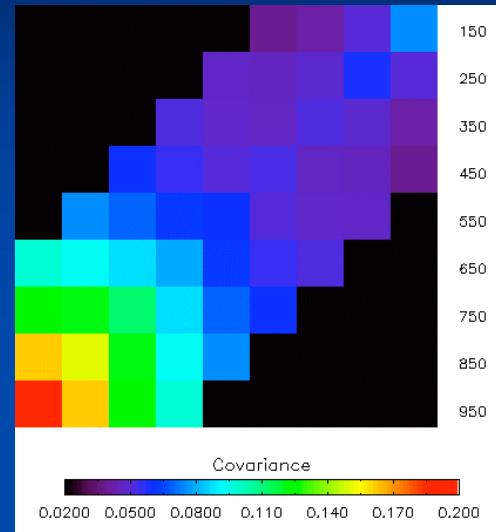
- Maximum a-posteriori (MAP)¹
- Gauss-Newton iterative scheme

$$\hat{x} = x_a + S_a K^T \left(K S_a K^T + S_\varepsilon \right)^{-1} \left(y - y_l + K(x_l - x_a) \right)$$

- x_a = a-priori estimate of CO profile
(US Standard profile)
- S_a = a-priori covariance matrix
(Modelled CO)
- K = CO Jacobians
(From forward model, RTTOV)
- S_ε = error covariance matrix
(Measurement errors)
- y = observed radiances
(Radiances observed by AIRS)
- x_l = linearisation profile
(Most recent estimation of CO in the iterative scheme)
- y_l = simulated radiances for linearisation profile
(Modelled radiances for our most recent estimate of CO)

Components of the Retrieval Method

- Forward Model – RTTOV
 - NWP SAF
 - Comparable with RFM
 - <http://www.metoffice.gov.uk/research/interproj/nwpsaf/>
- Prior covariance, \mathbf{S}_a
 - STOCHEM + manual adjustment
- Prior CO, \mathbf{x}_a
 - AFGL US standard
- AIRS level 2 products
 - Cloud cleared radiances
 - ~50 channels
 - 4.67 μm - CO fundamental
 - $T, H_2O, T_{\text{surf}}, \epsilon$
 - Errors contribute to \mathbf{S}_ϵ
- Averaging kernels
 - Peak around 500 hPa
 - ~1 degree of freedom



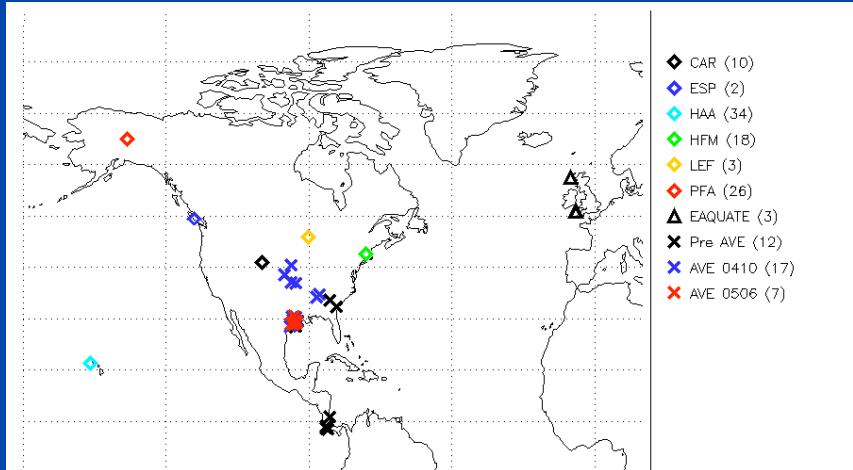
Validation Data

■ Sources

- NOAA – CMDL
 - <http://www.cmdl.noaa.gov/>
 - 6 sites
 - Sept 02 – Dec 04
- FAAM – EAQUTE
 - <http://www.faam.ac.uk/>
 - UK Met Office and NERC
 - Sept 2004
- NASA – AVE
 - <http://www.espo.nasa.gov/>
 - 3 missions
 - Jan 04, Oct/Nov 04, Jun 05

■ Coincidence criteria

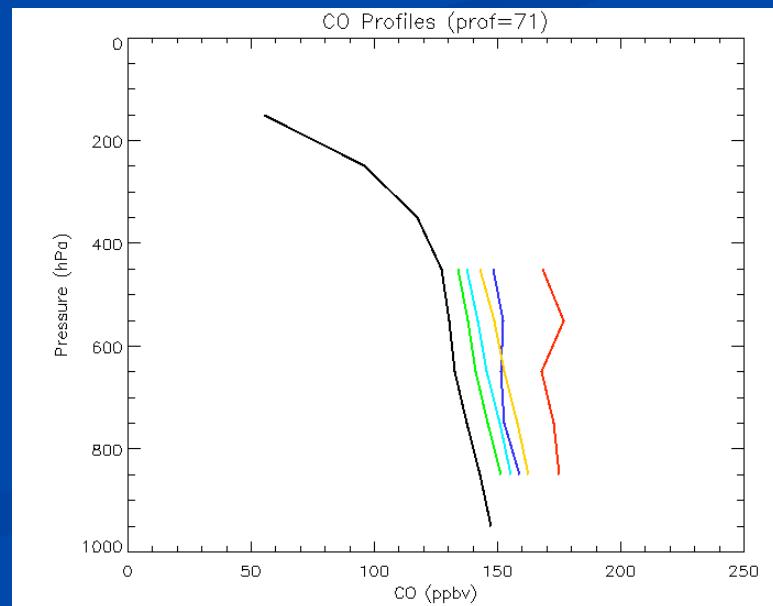
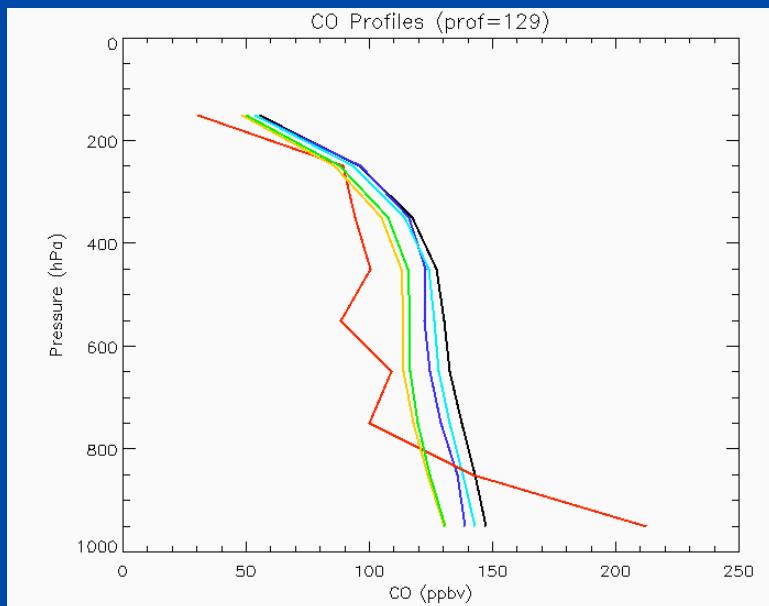
- ± 6 hours
- $\pm 1^\circ$ Latitude/longitude



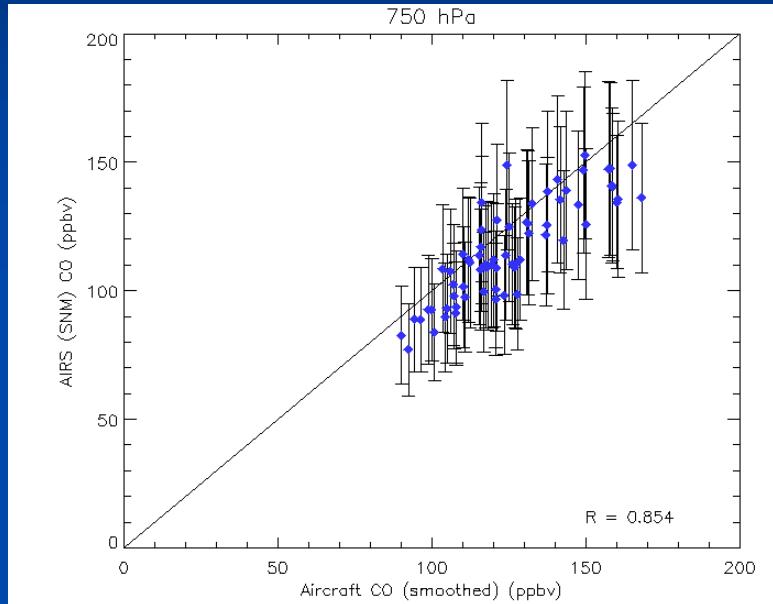
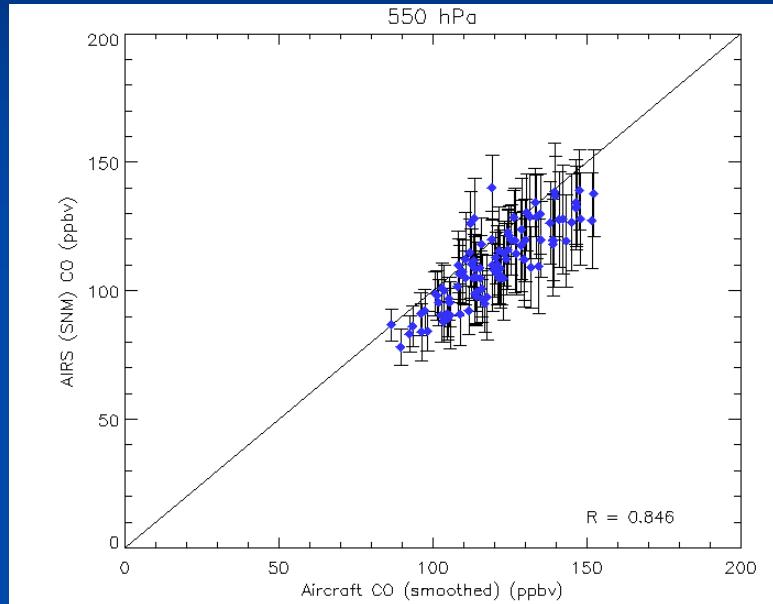
Profile Retrievals

- Retrievals on 9 levels
- x_a = AFGL US Standard
- $X_{\text{smooth}} = x_a + A(x_m - x_a)$
 - x_m = aircraft CO

Black – x_a
Green - SNM
Red – Aircraft
Orange -Smoothed Aircraft
Dark Blue – AIRS
Light Blue – Smoothed AIRS

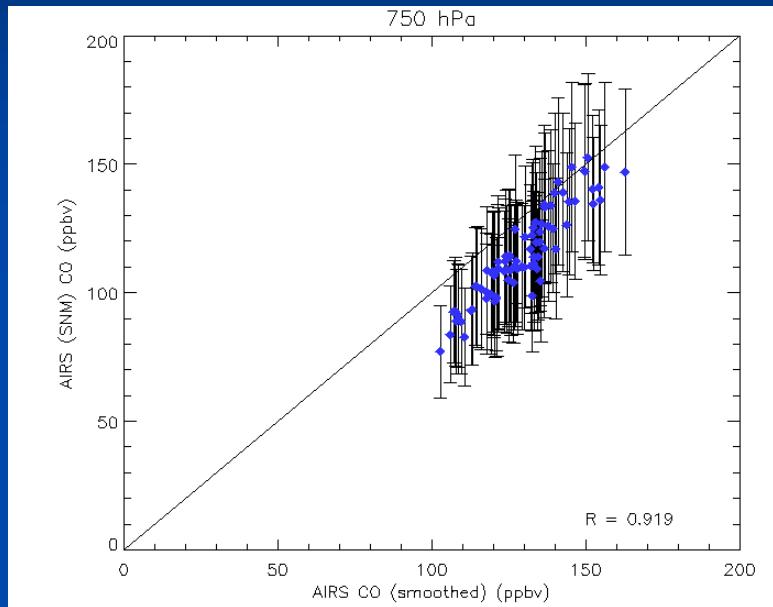
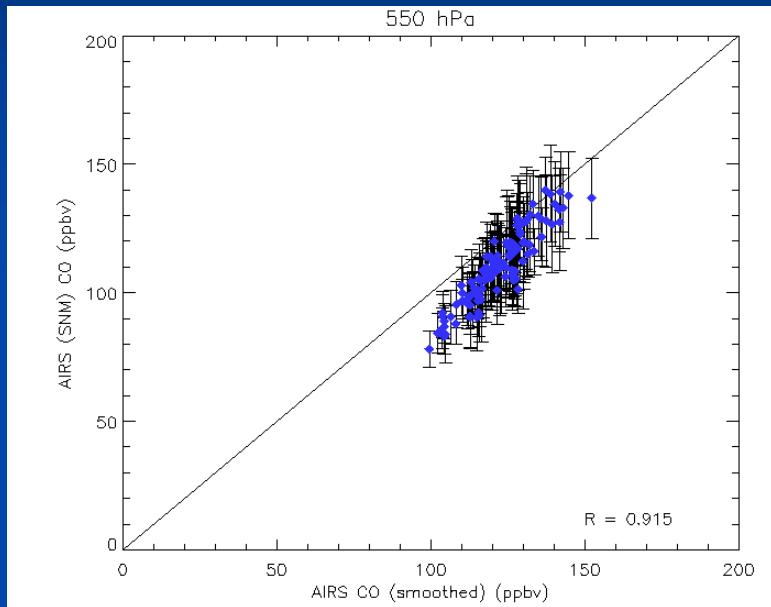


CO on Levels – Aircraft vs SNM



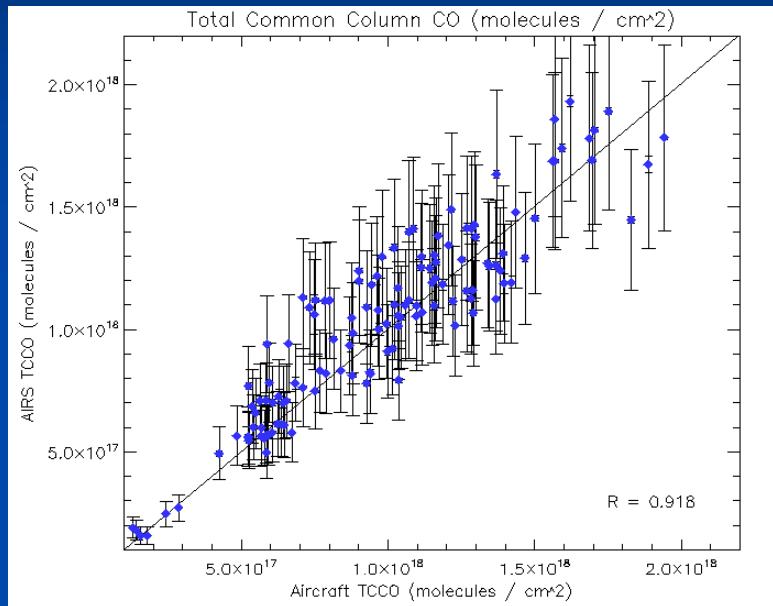
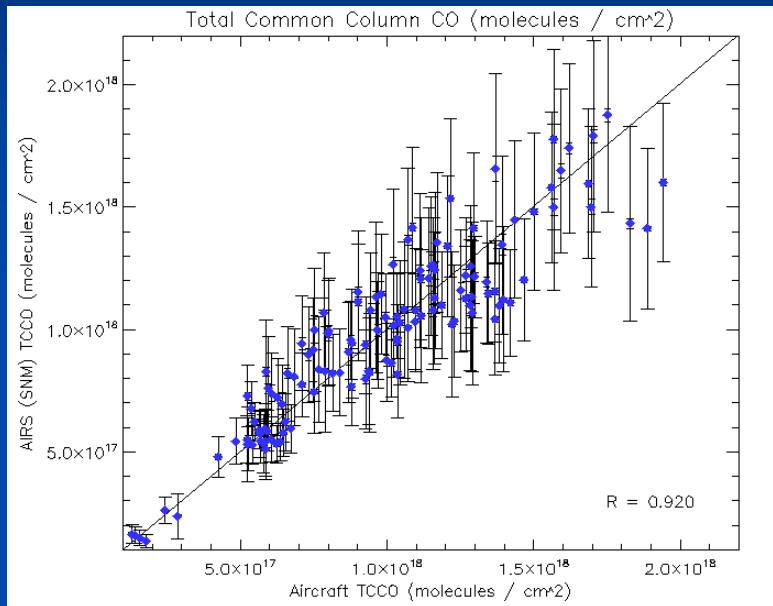
- SNM vs Aircraft (smoothed)
- % a-priori < 50%
- Negative bias
- Good Correlation
- Larger errors at levels towards top and bottom of atmosphere
- Fewer pixels with % a-priori < 0.5
- Larger contribution from x_a at these levels

CO on Levels – AIRS vs SNM



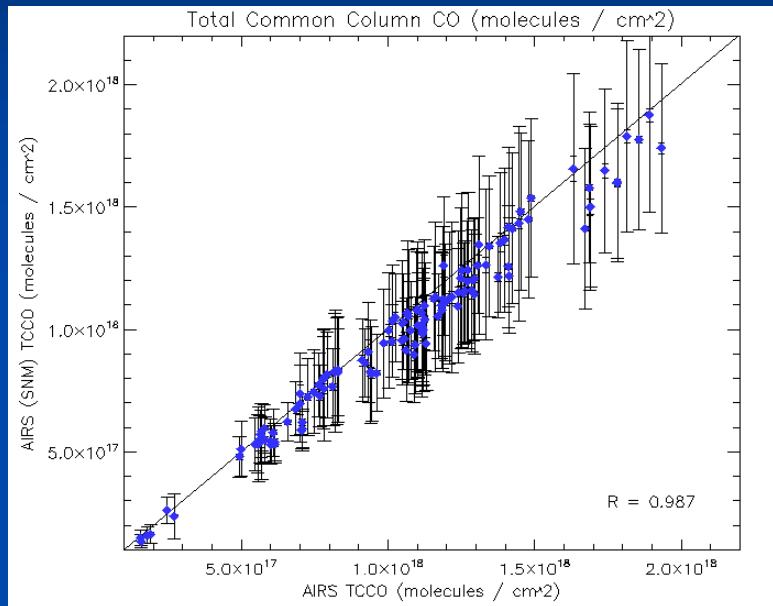
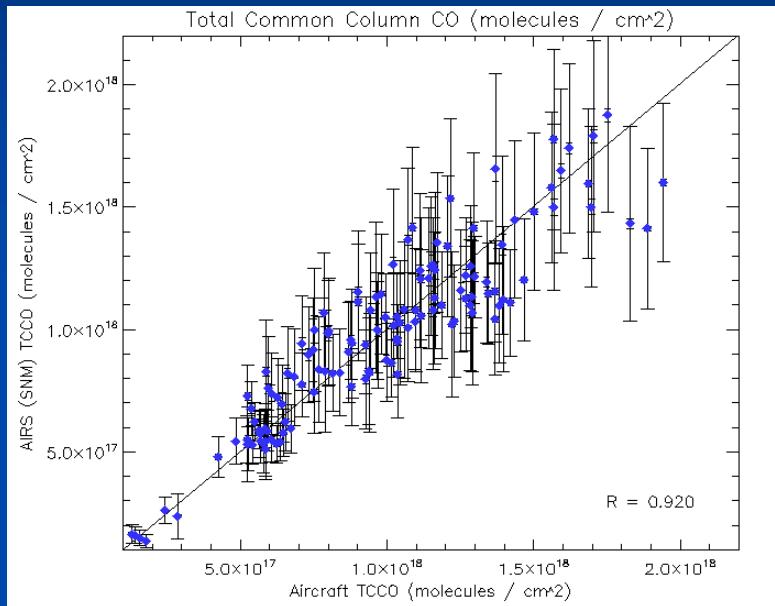
- SNM vs AIRS (smoothed)
- % a-priori < 50%
- High correlation
- Negative bias
- Same behaviour as Aircraft vs SNM at top and bottom of atmosphere

Total Common Column CO – No smoothing



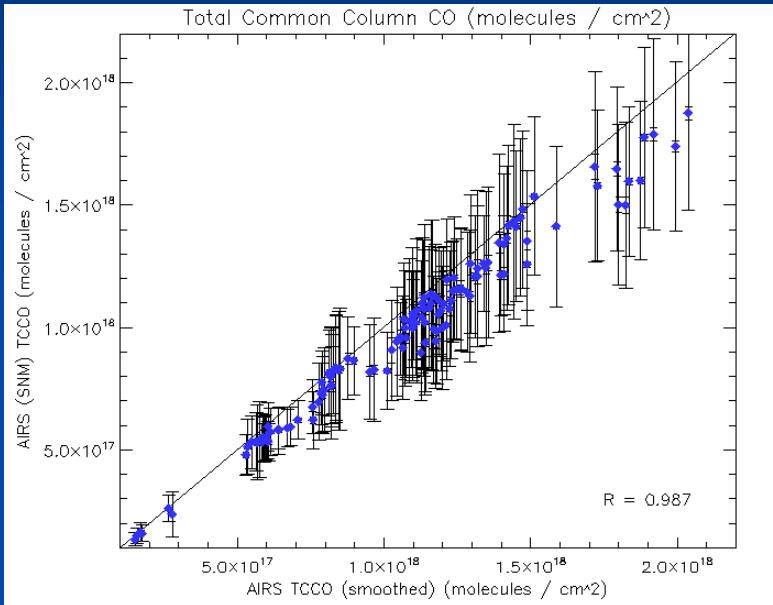
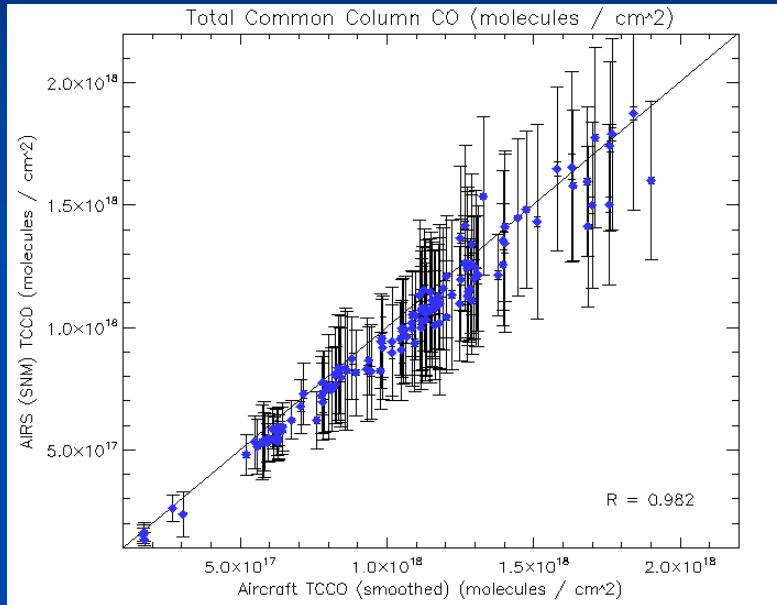
- All data included (any % priori)
- Aircraft vs SNM
 - Good correlation
 - Problems with high CO values
- Aircraft vs AIRS
 - Good correlation
 - Better with high CO values

Total Common Column CO – No smoothing



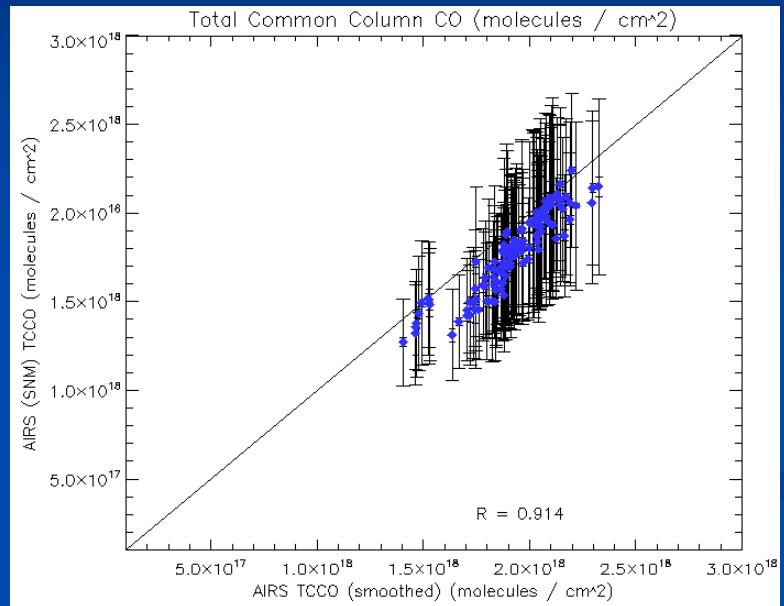
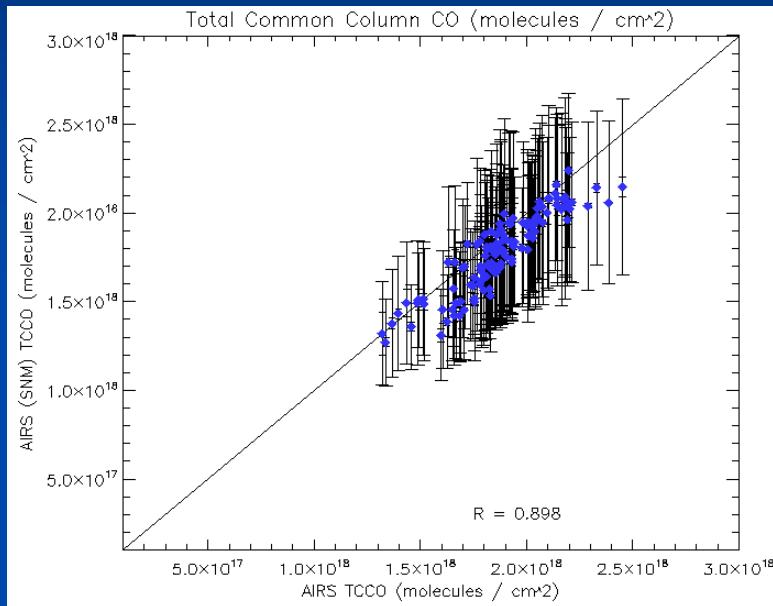
- All data included (any % priori)
- Aircraft vs SNM
 - Good correlation
 - Problems with high CO values
- AIRS vs SNM
 - Excellent correlation
 - Similar at high CO values

Total Common Column CO - Smoothed



- Smoothed
 - % a-priori < 50%
- Aircraft vs SNM
 - Excellent correlation
 - Still problems with high CO values
- AIRS vs SNM
 - Excellent correlation
 - Problems with high CO values

Total Column CO – All levels

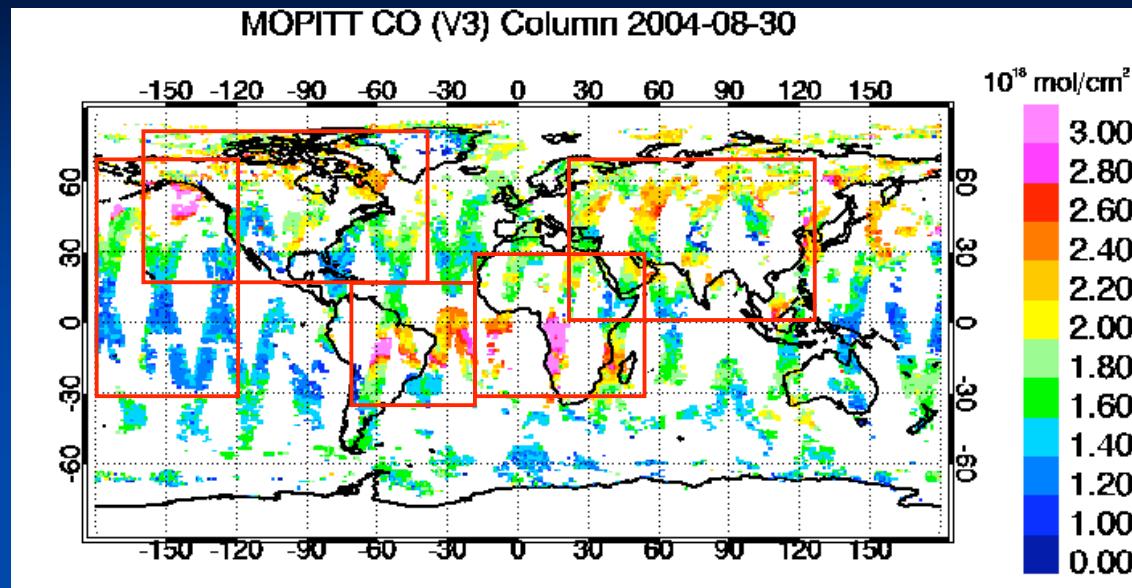


- All levels (not just in common with aircraft)
- % a-priori < 50%
- High Correlation

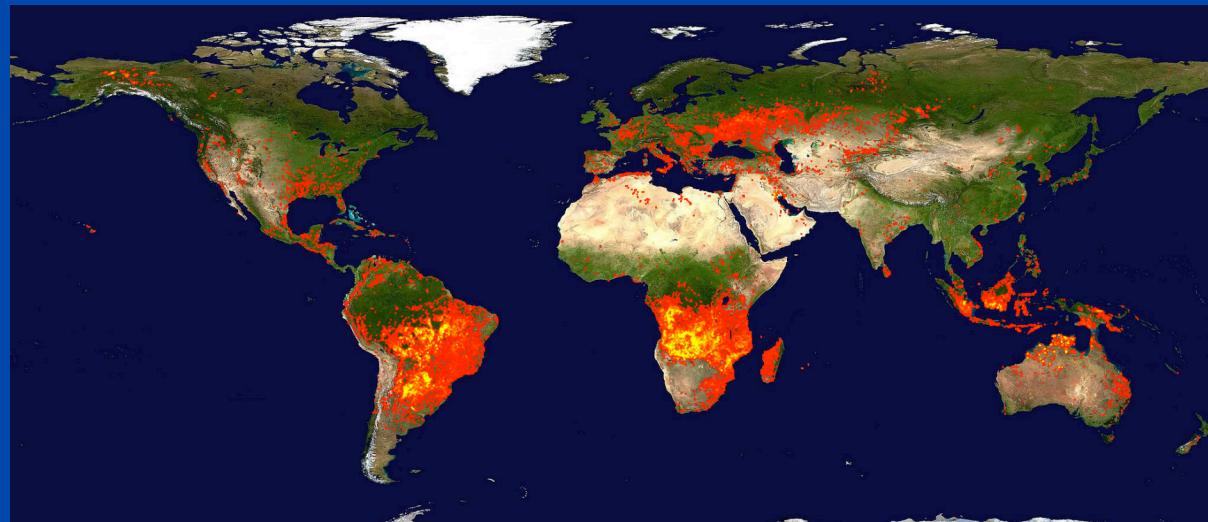
Validation Study - Conclusions

- Total Column CO
 - Good correlation between SNM and Aircraft
 - Comparable to AIRS product
 - Good correlation with AIRS product for full column
 - Negative bias in SNM relative to AIRS
- CO Profiles
 - Good correlation on mid-troposphere levels but not so good at top and bottom
 - Heavy reliance on prior at top and bottom of the profile
 - Larger errors at these levels

Retrievals for 30th Aug 2004

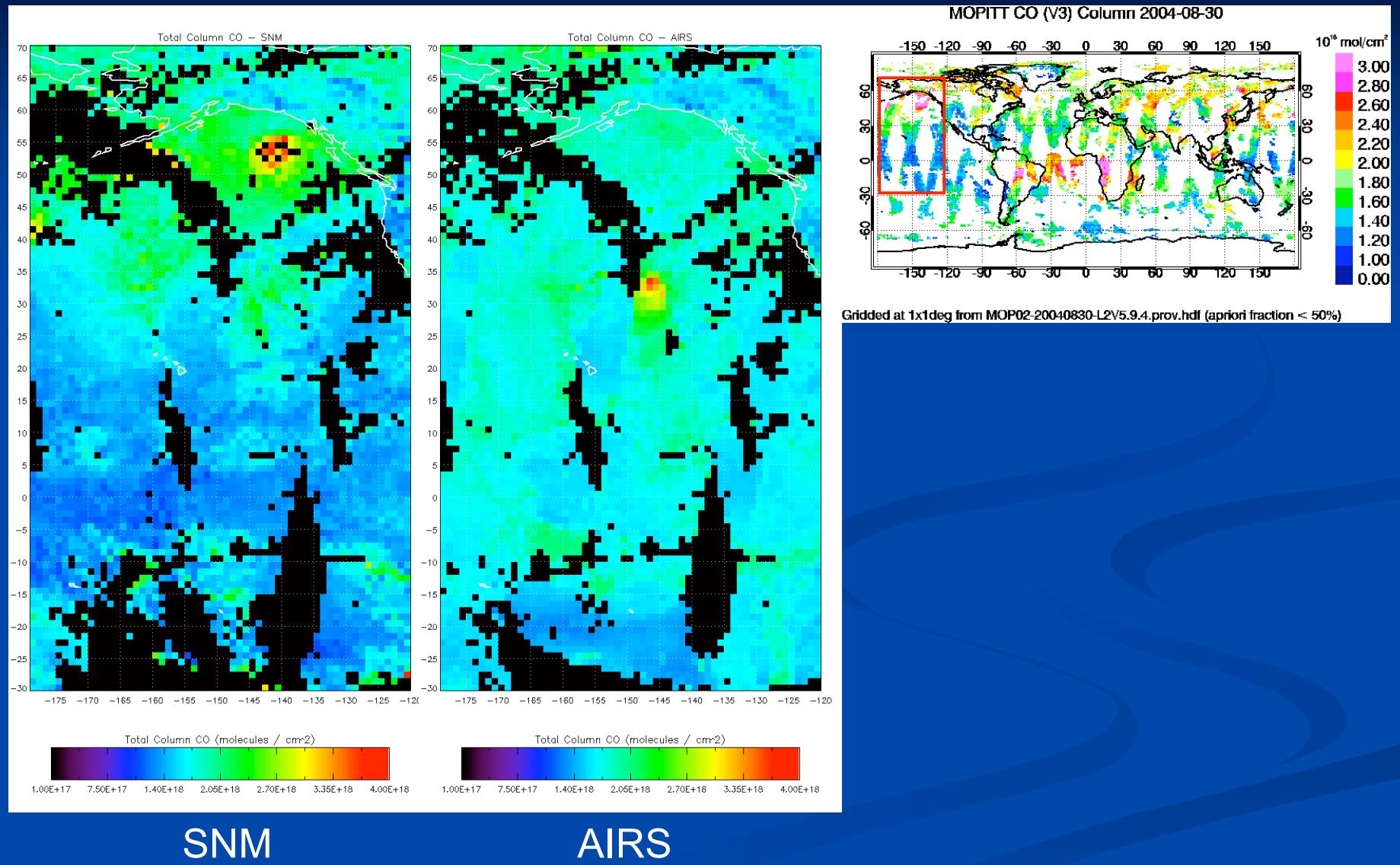


<http://mopitt.eos.ucar.edu/mopitt/data/plots/mapsv3.html>



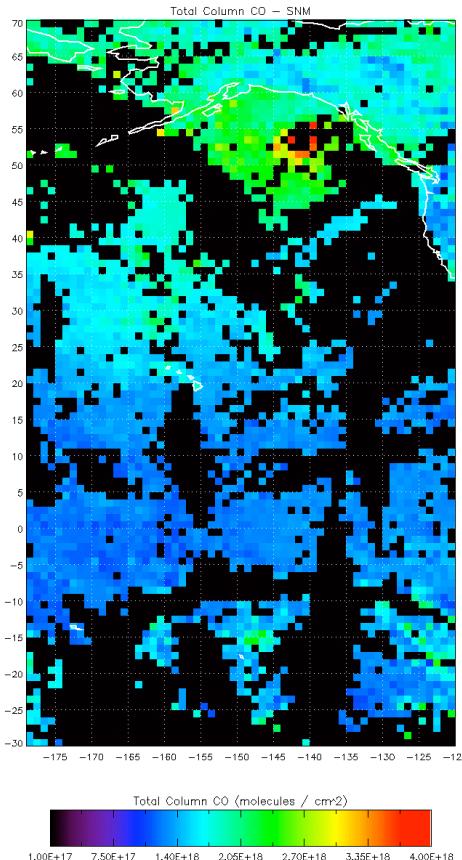
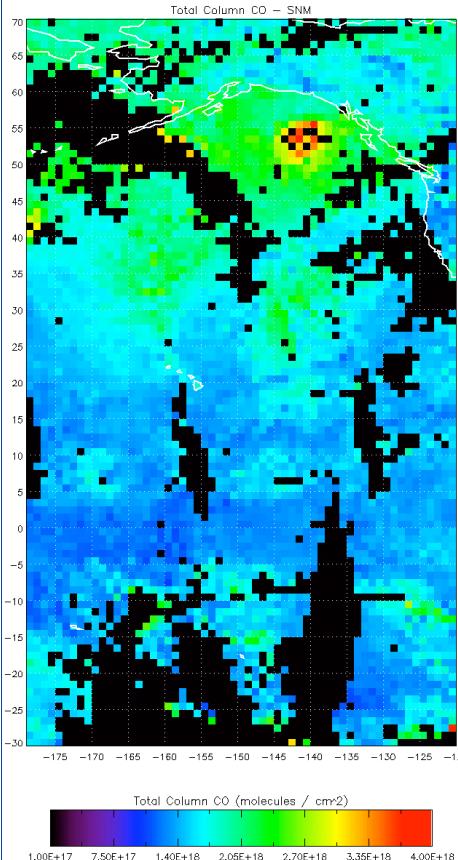
<http://rapidfire.sci.gsfc.nasa.gov>

Total Column CO – Region 1



Total Column CO – Region 1

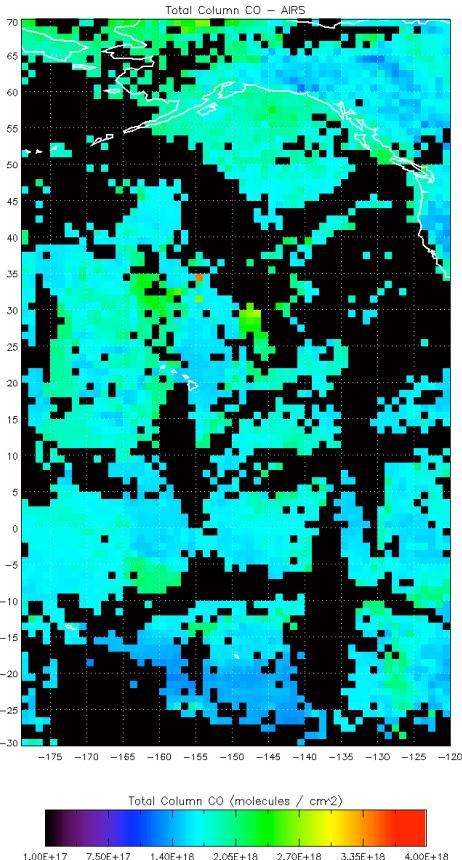
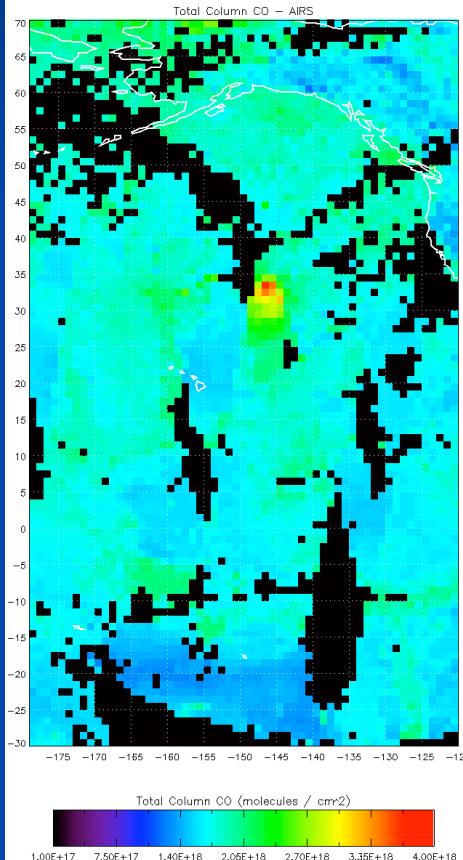
SNM



All

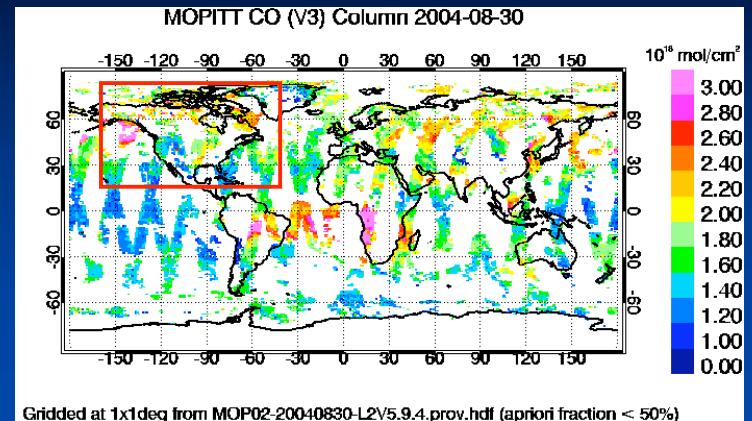
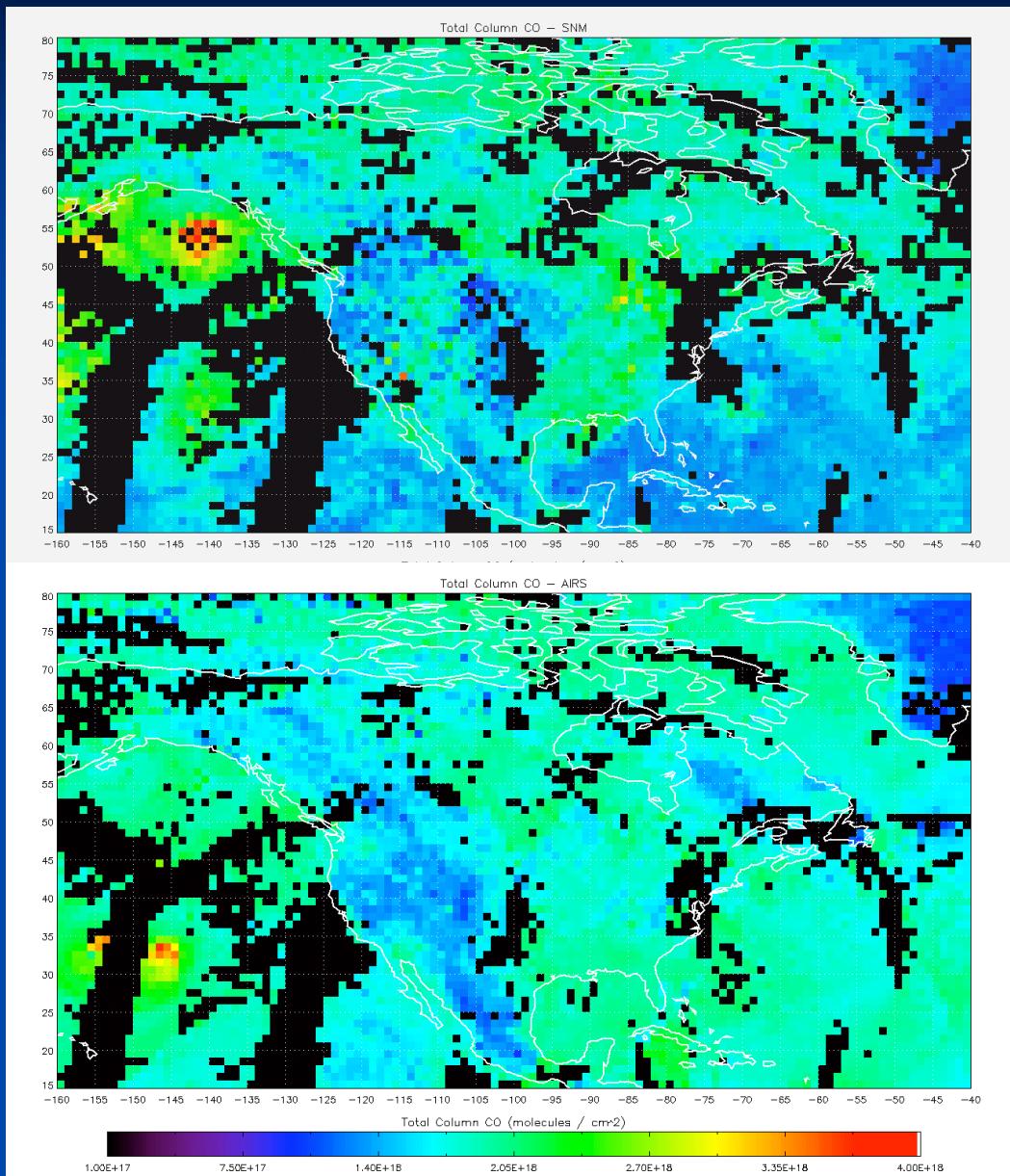
QF < 2

AIRS



QF < 2

Total Column CO - Region 2

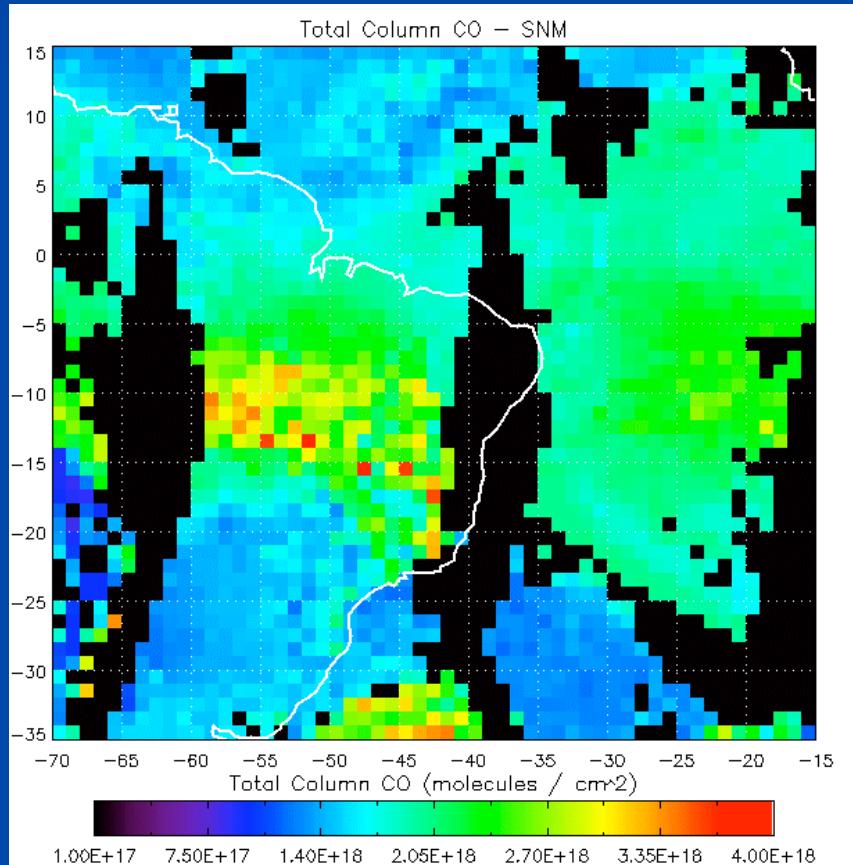


SNM

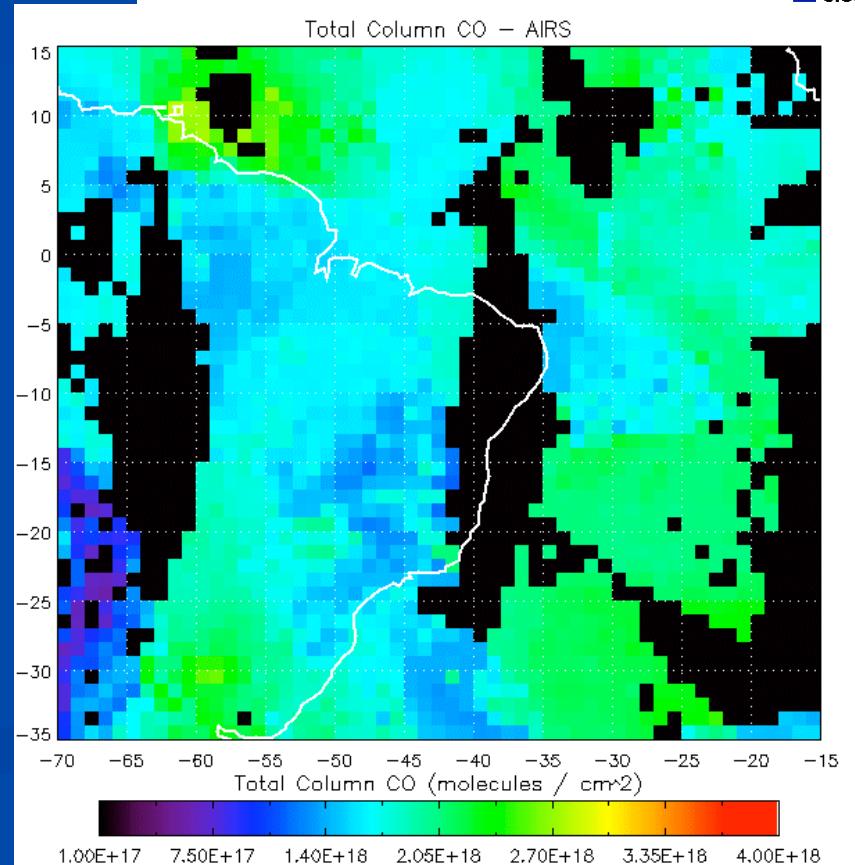
AIRS

Total Column CO - Region 3

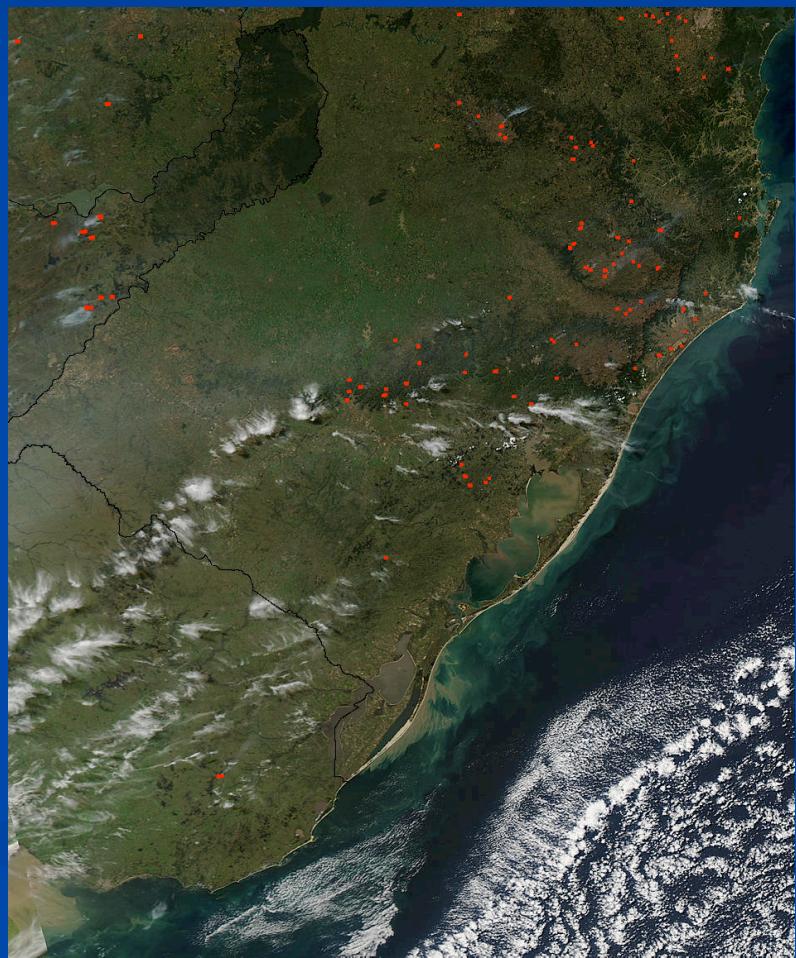
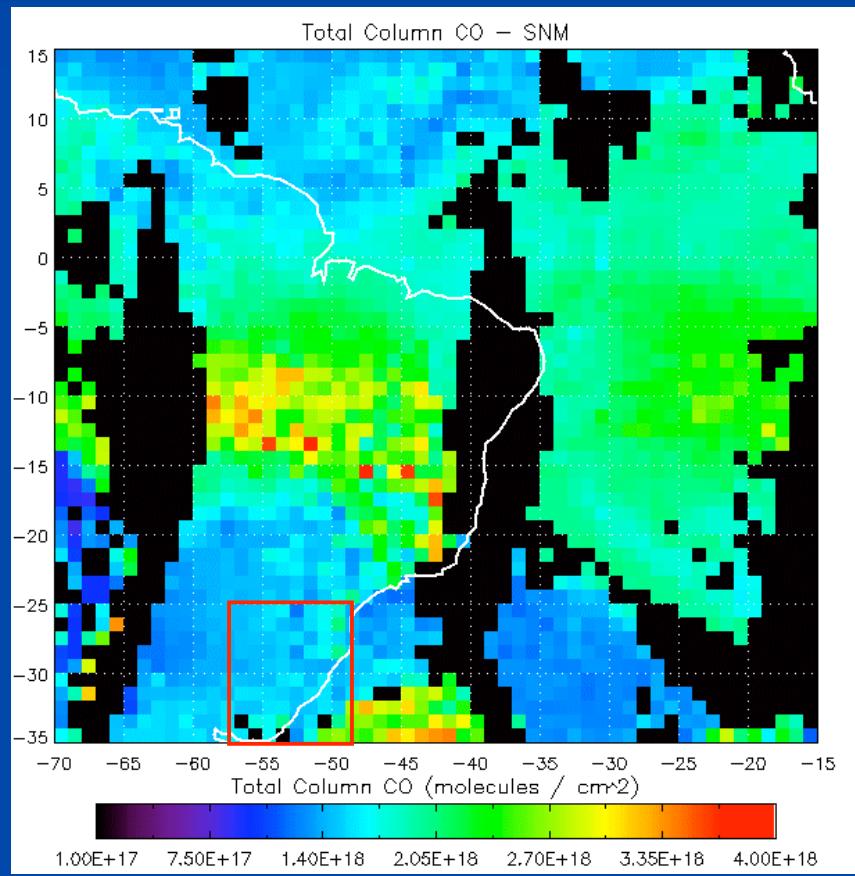
SNM



AIRS

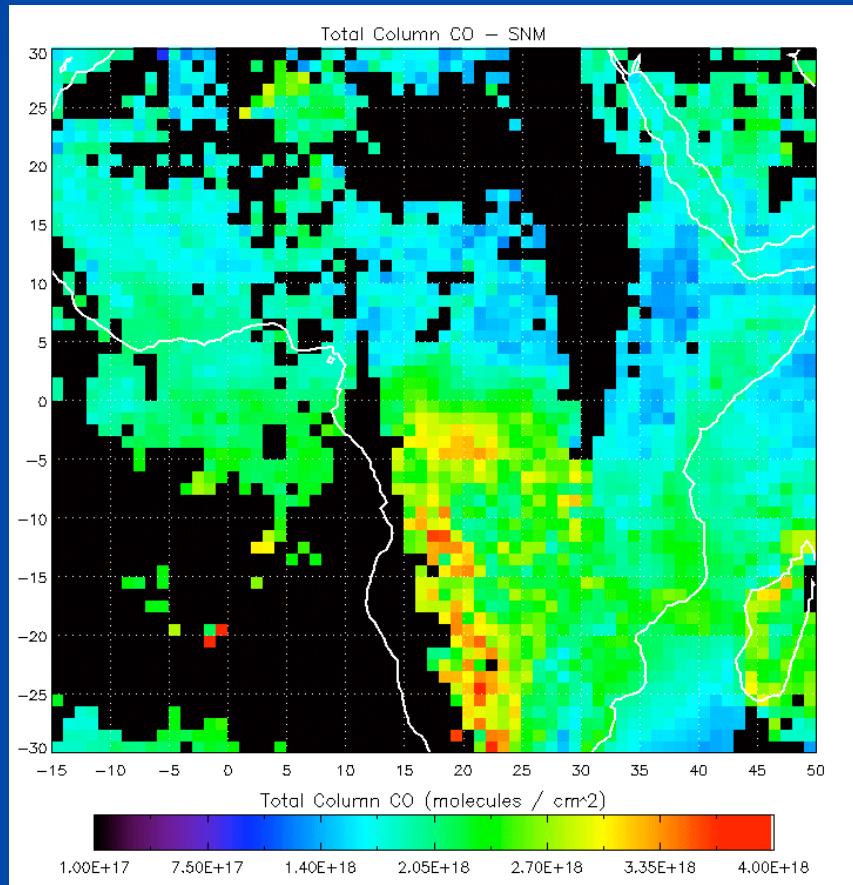


Total Column CO - Region 3

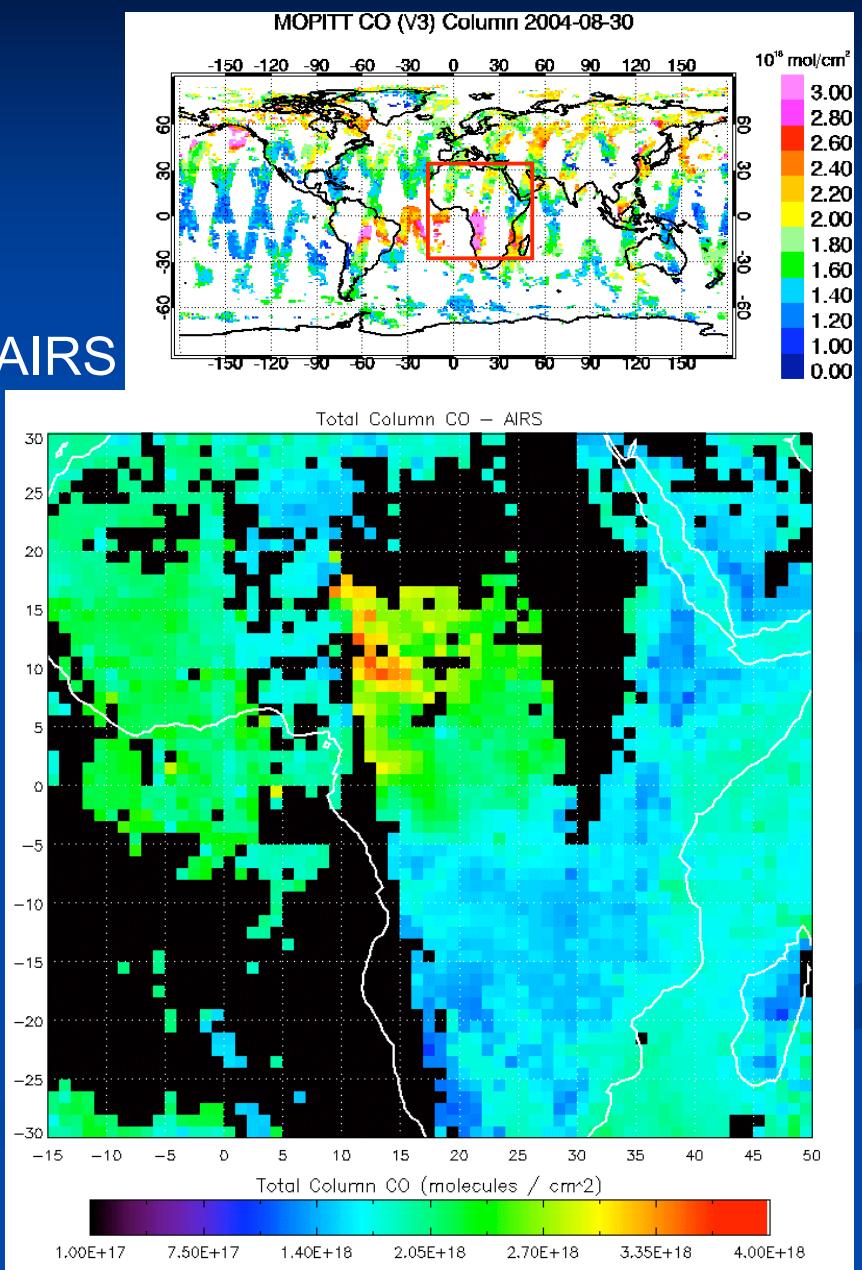


Total Column CO - Region 4

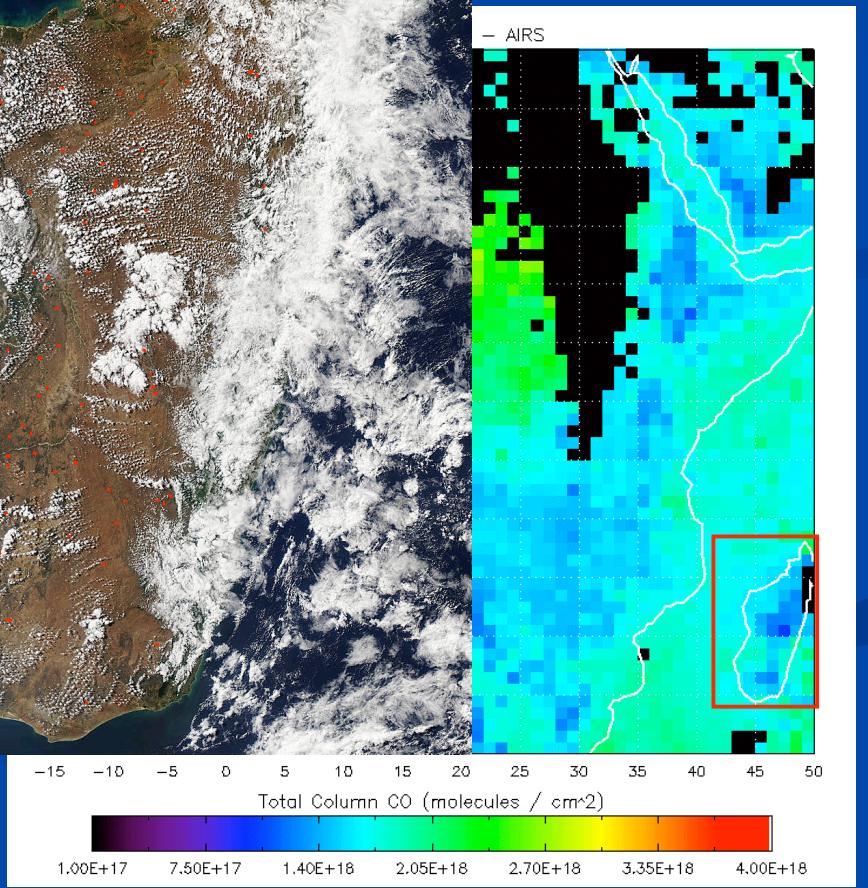
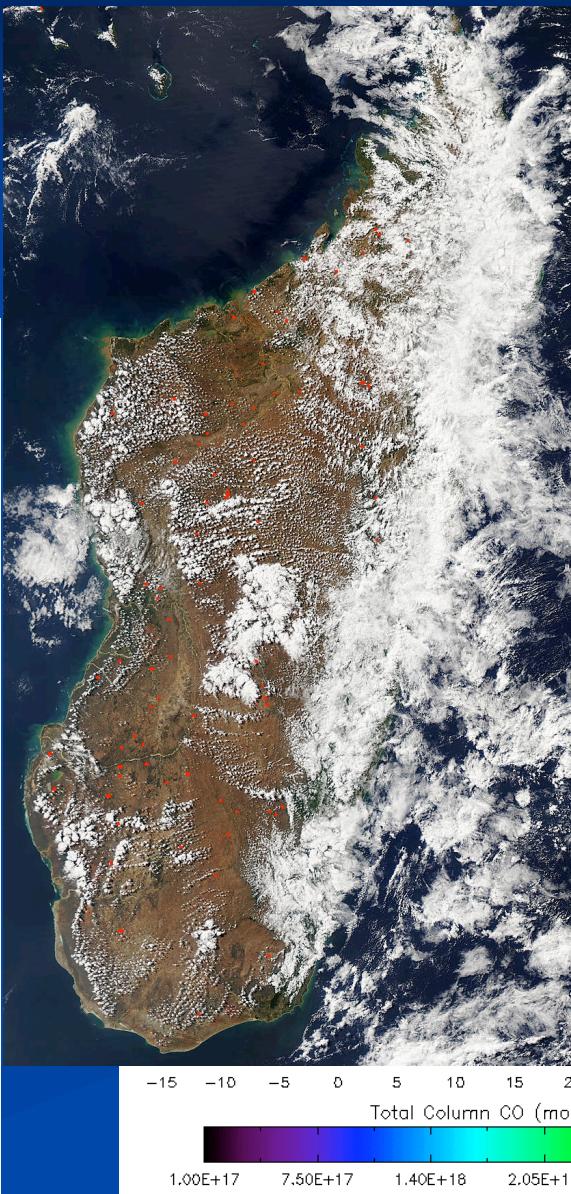
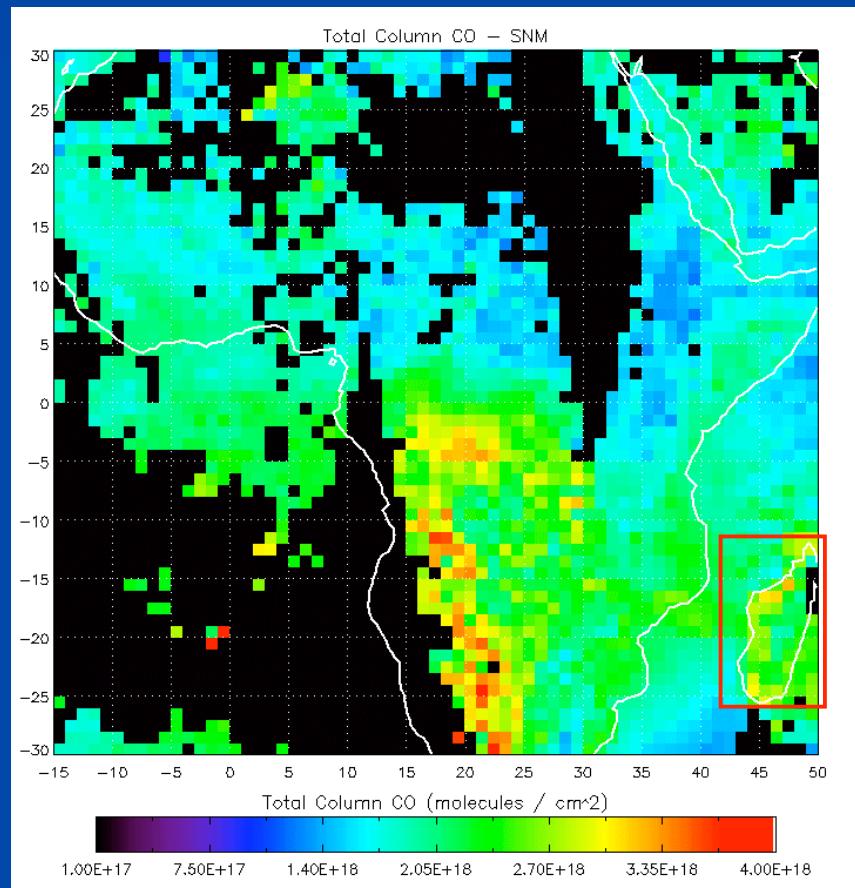
SNM



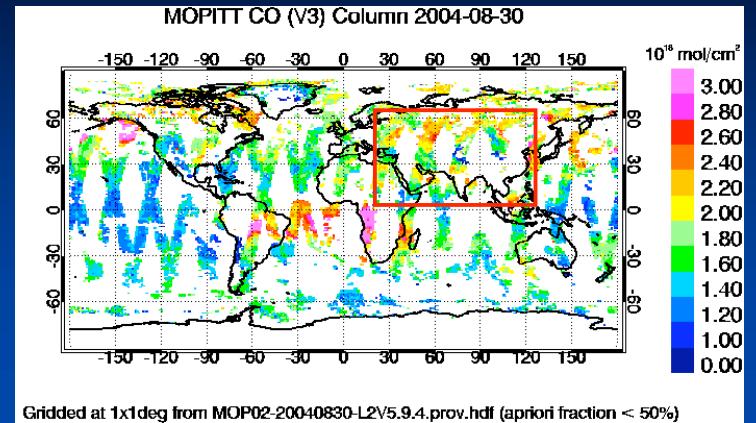
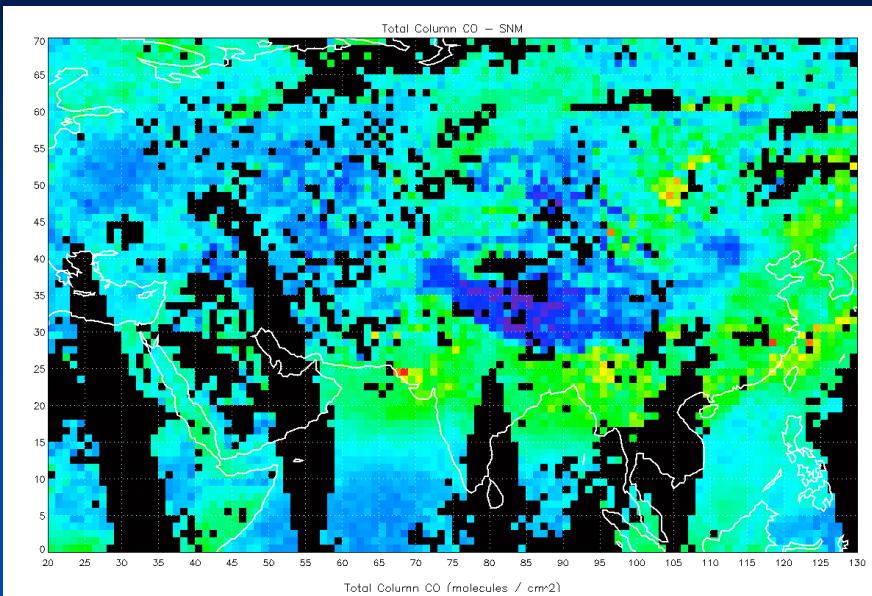
AIRS



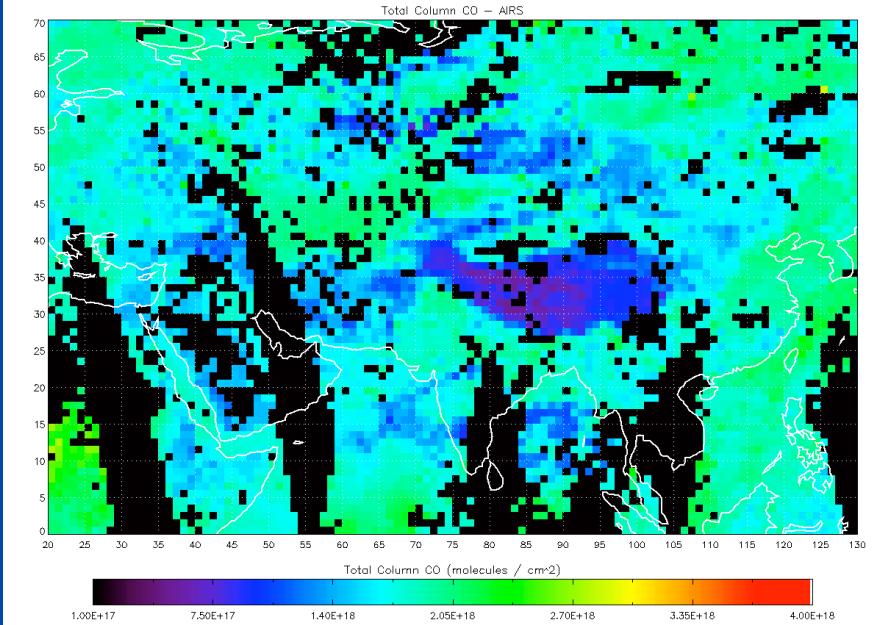
Total Column CO - Region 4



Total Column CO - Region 5



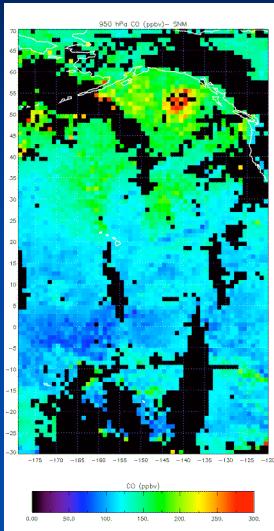
SNM



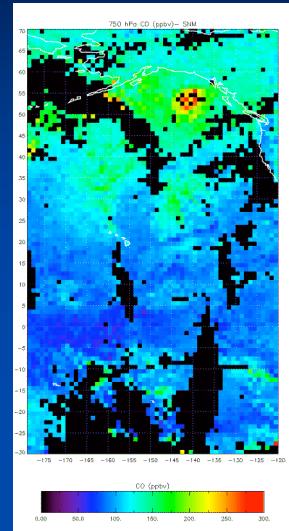
AIRS

Region 1 – Profile Levels

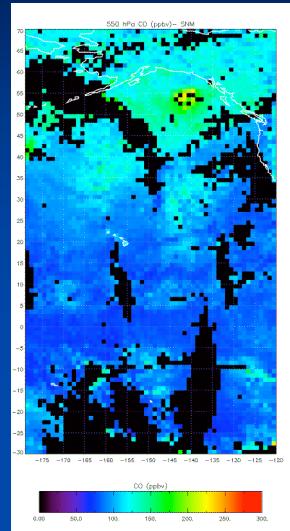
SNM



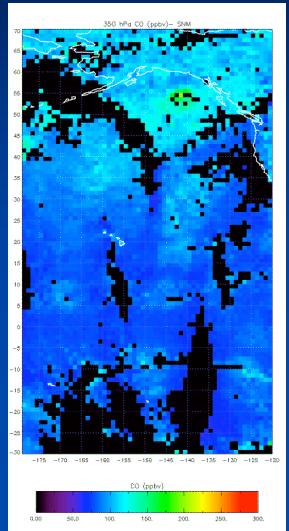
950



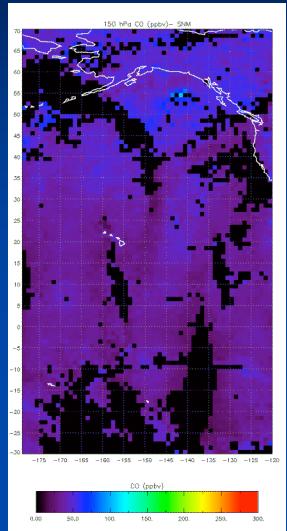
750



550

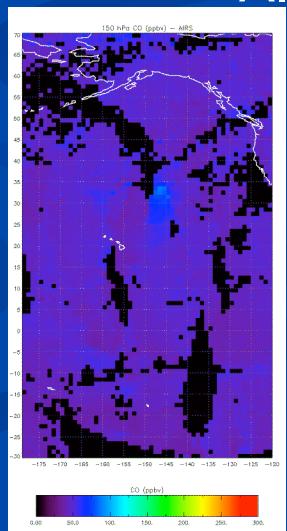
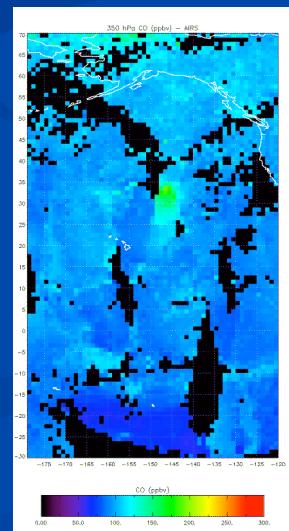
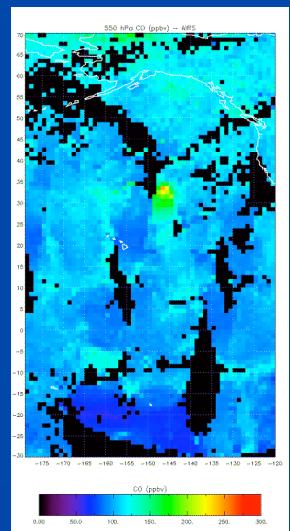
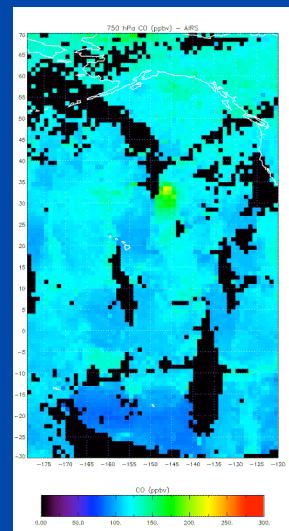
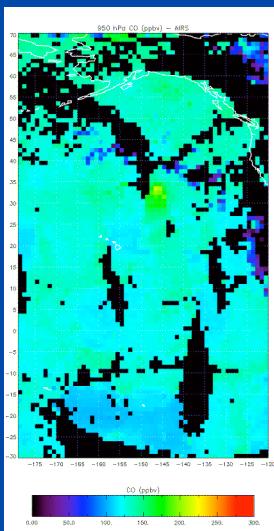


350



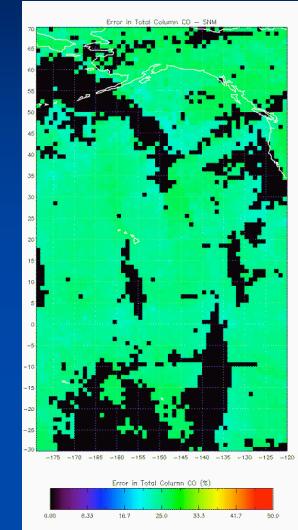
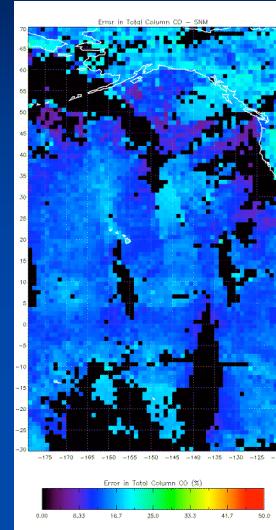
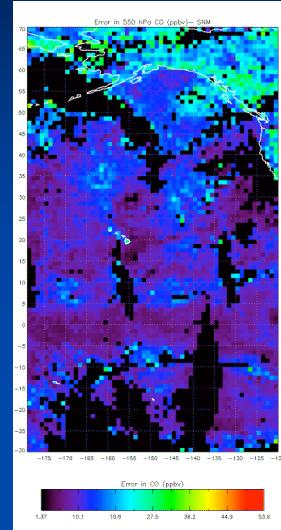
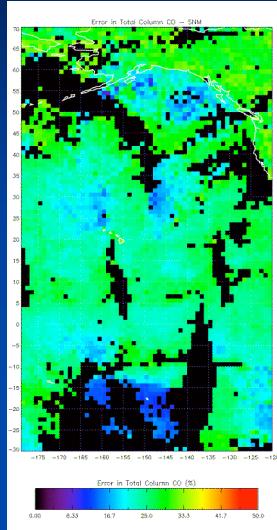
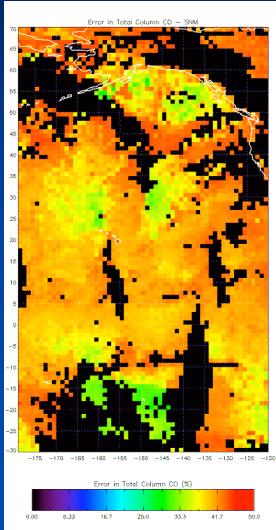
150

AIRS



Region 1 – Profile Level Errors

SNM



950

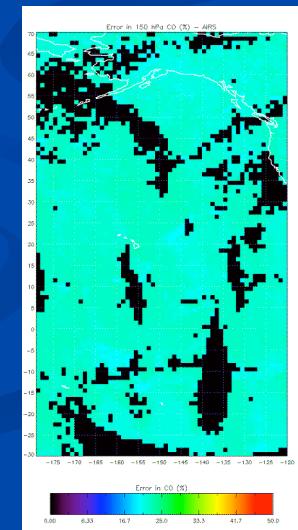
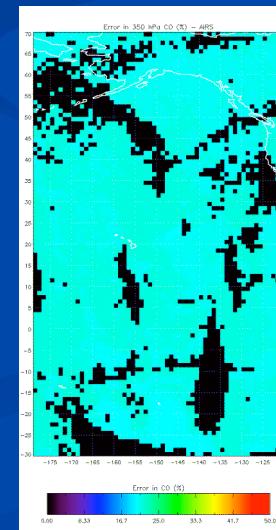
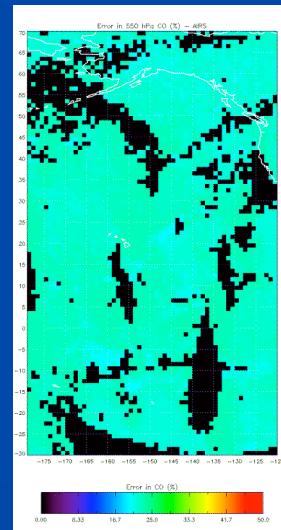
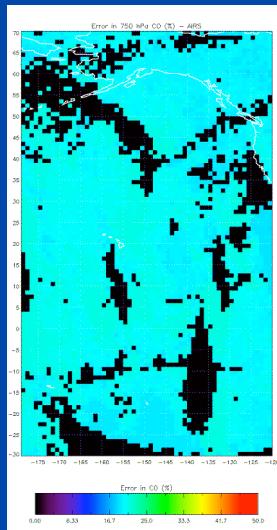
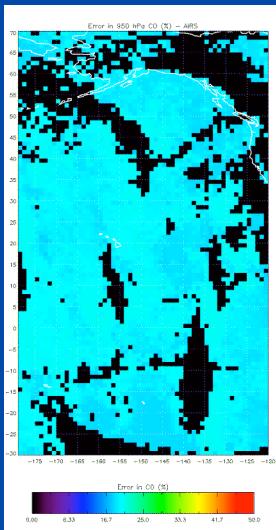
750

550

350

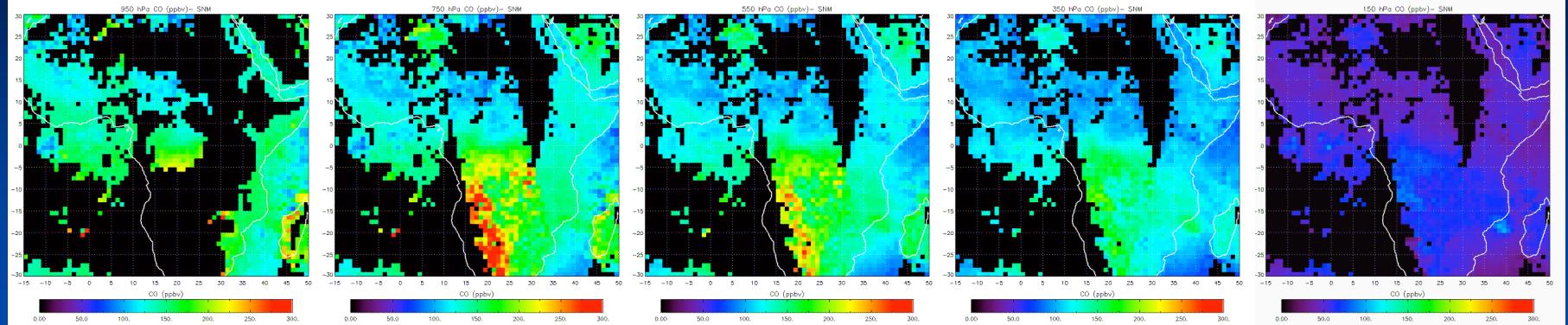
150

AIRS

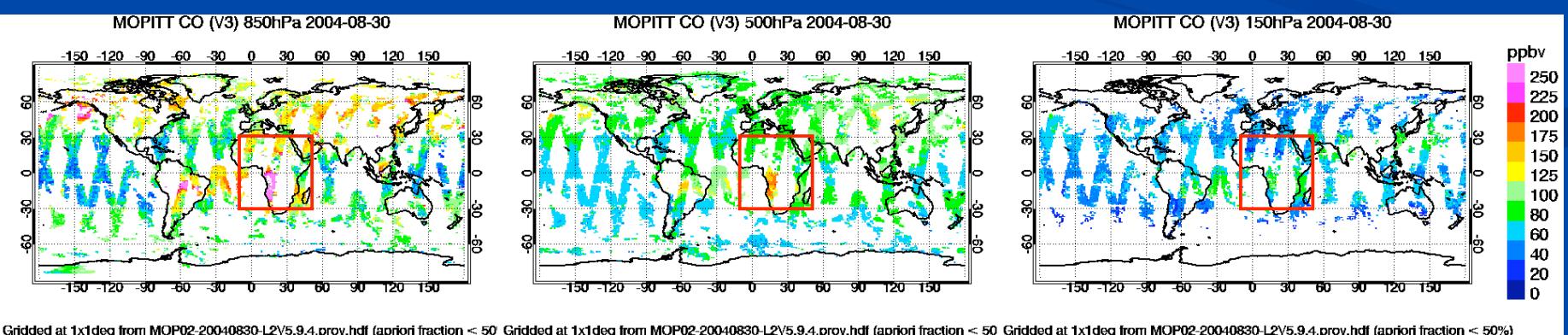
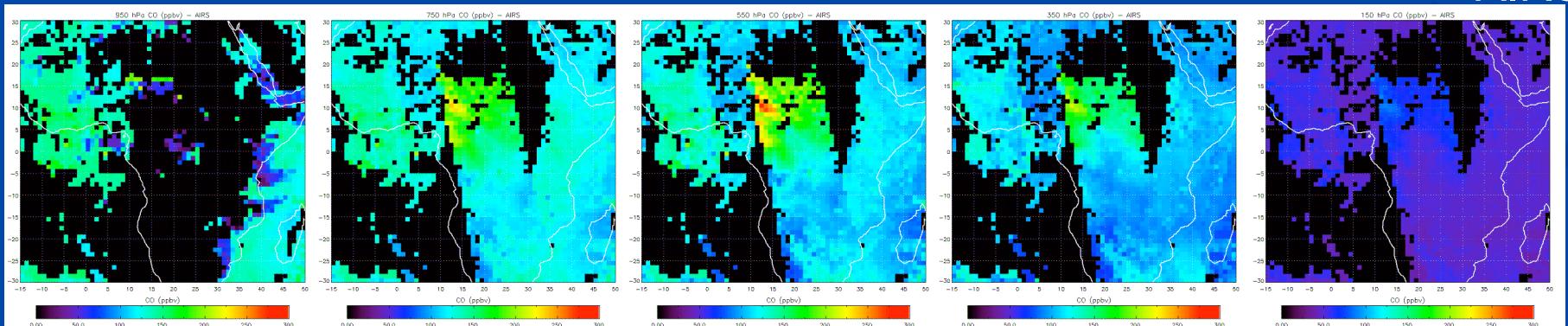


Region 4 – Profile Levels

SNM

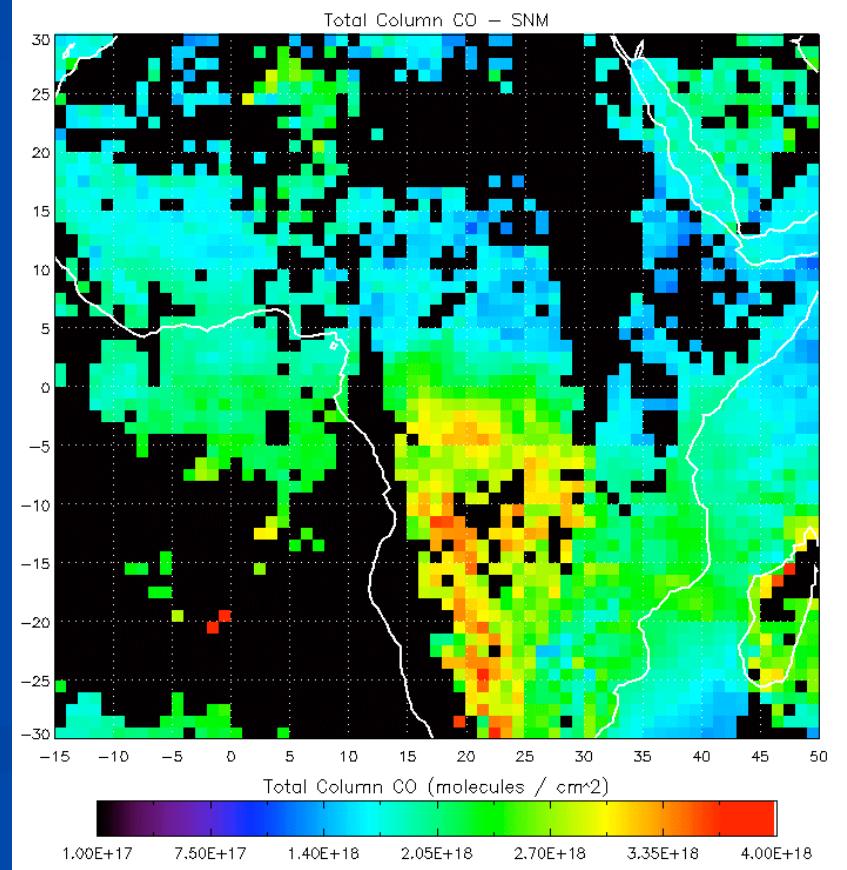
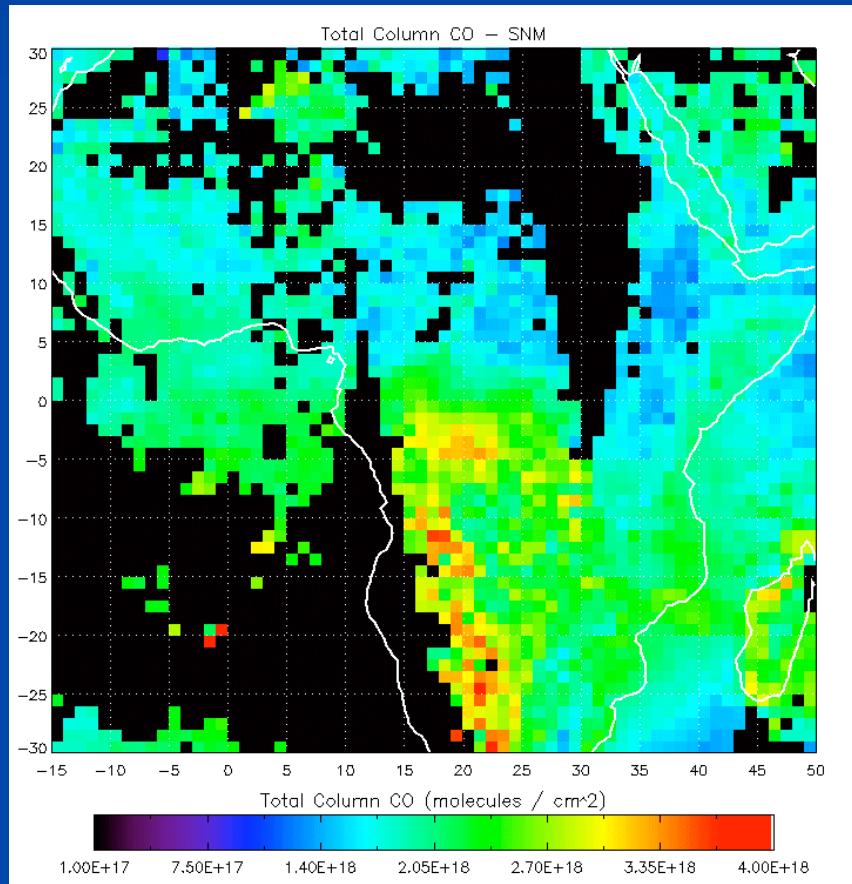
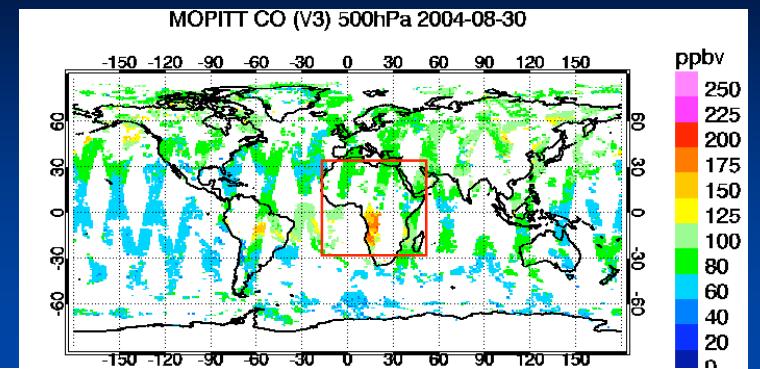


AIRS



ppbv
250
225
200
175
150
125
100
80
60
40
20
0

Region 4 – All data vs a-priori < 0.5



Summary

- Alternative retrieval scheme
 - Optimal estimation - MAP
 - RTTOV
 - S_a – STOCHEM + manual adjustment
- Validation study
 - Independent aircraft projects
 - Variety of locations
 - Over 100 profiles
 - Good correlation between SNM, Aircraft and AIRS
- Regional comparison
 - Broadly similar to AIRS and MOPITT
 - Significant differences between AIRS and SNM in some areas
 - Quite reasonable error structure (vertical and horizontal)
- Problems
 - Large residuals ($y - y_i$) in some areas.
 - Low radiance error estimates
 - Dubious retrievals
 - Need better understanding of AIRS L2 products
- Future Work
 - Further comparison with AIRS (V4 and V5) and MOPITT
 - Explain the differences between AIRS and SNM
 - Application of retrieval scheme in CO case studies.